

## **GEOS-5 Atmospheric Data Assimilation System Changes: From GEOS-5.2.0 (MERRA) to GEOS-5.11.0**

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There have been several upgrades in both the model and the analysis since the GEOS-5.2.0 system that was used for MERRA and the previous version of the near-real-time forward processing stream for NASA instrument teams. Most important among these is the switch to the cubed-sphere grid for the AGCM and the update to the analysis that facilitates assimilation of new data types.

Since several versions of the GEOS system have been used to generate products that have been served through the NCCS Data Portal, the changes are documented sequentially.

### **From GEOS-5.2.0 (MERRA) to GEOS-5.7.2**

#### **Model Changes**

##### *AGCM Component*

- i) Stochastic Tokioka version of RAS (resolution-dependent stochastic limitation of cumulus entrainment).
- ii) Modified MoistGridComp and cloudnew to locally decrease optical depths based on a sfc wind speed threshold. The main impact is over polar ice.
- iii) Increase re-evap of snow and ice, overall decreased rates of autoconversion, and re-tuned radiative forcing to accommodate a wetter atmosphere.
- iv) Turbulent surface layer parameterization changed to the Monin-Obukhov scheme.
- v) Turbulence: Inhibit action of Lock scheme in the presence of wind shear, increase overall action of Louis scheme near the surface, and implement a new Louis turbulence length scale based on PBL height.
- vi) The option for a new z0 formulation over oceans was implemented. It increases the drag for moderate surface wind speeds and decreases it for hurricane strength winds.
- vii) Removed viscous sub-layer over LAND, but viscous sub-layer included over LAKE, LANDICE, and SEA-ICE.
- viii) Modified RHCRIT profile to a specified tanh profile, starting at 1.0 near the surface over oceans and turning near 800 mb to a resolution-dependant minimum value. Over land the near-surface value is also resolution-dependant and lower than over oceans.
- ix) A new Gravity Wave Drag Parameterization capable of producing a QBO was implemented.
- x) New boundary datasets are introduced: an updated topography over Greenland, and new lai\_green (leaf area index and greenness fraction), nirdf, and visdf (near infrared and visible diffuse solar irradiance) datasets.
- xi) Corrected bug in using the topo\_TRB\_var dataset (related to Turbulence VARFLT). The model had compensating errors which reduced the impact of using the variance\*\*2 (rather than the variance).

- xii) Added 5 m/sec maximum wind speed for VARFLT calculation to limit instabilities.
- xiii) Added guard in surfacelayer.F90 to prevent division by zero. Impact is very small due to limiting cases invoked when division by zero occurred.
- xiv) Modified surfacelayer.F90 to prevent creation of negative RHO due to small inconsistencies in sea-ice dataset.
- xv) Fixed bug in GEOS\_IrradGridComp.F90 to correct time-truncation error for updates (off by one step).
- xvi) Default CO<sub>2</sub> set to  $380 \times 10^{-6}$ .
- xvii) Latent Heat of Fusion constants have been updated to more accurate values.
- xviii) Total ozone (TO3) replaced by Total odd oxygen (TOX) in GCMPROG.rc.tmpl.
- xix) Replaced lwi with model land fractions in HISTORY.rc.tmpl.

#### *Land Surface Component*

- (i) Fixed SPSNOW (Spurious Snow) diagnostic.
- (ii) Updates to MAPL\_Constants, catch\_constants, getcdh.code and catchment.F90. These updates attempt to reduce extreme cold temperatures over snow during clear-sky nighttime conditions.
- (iii) Updates to GEOS\_CatchGridComp and catchment.F90 fixed SNOW\_DEPTH and SNOW\_WATER\_EQUIV interface error.

### **Analysis Changes**

- (i) The GSI was updated to accommodate new observing systems (IASI, GPSRO) using CRTM Release 2.0.2.
- (ii) The background error statistics were updated to those for GEOS-5 (gmao31Mar2009\_fp+oz\_fix)
- (iii) A vortex relocater was implemented.
- (iv) Fixed updating of ozone analysis increment. Previous versions (including MERRA) incorrectly assumed the analysis increment was in mass-mixing-ratio. However, the analysis provides ozone increments in volume-mixing-ratio.
- (v) Enforced positive-definiteness of specific humidity, ozone, and cloud water condensate.
- (vi) The following observation changes were made:
  - GPS Refractivity from GRACE-A and METOP-GRAS
  - Cloud Drift winds (below 850 mb) from METEOSAT (EUMETSAT)
  - Cloud Drift winds (above 850 mb) from METEOSAT (EUMETSAT)
  - ASCAT added
  - Tightened gross check of all conventional observations (those in prepbufr); roughly most temperature observations had at least 1 K reduction in gross check error, and most wind observations about 1.5 m/s reduction.
- (vii) The window channels for AMSUA - 1,2,3 and 15 – were made passive.
- (viii) Radiosonde station 64650 (Bangui, Central African Rep.) was added to the blacklist.

### **Other**

- i) Output uses NetCDF4 (HDF5).

- ii) Time-varying aerosols for radiation calculation input from GOCART coupled to GEOS-5.
- iii) Aerosol assimilation provides aerosol updates

## **From GEOS-5.7.2 to GEOS-5.9.1 (FP-IT)**

### **Model Changes**

#### *AGCM Component*

- xx) Model configuration updated to the cubed-sphere version of the horizontal grid.
- xxi) Code to calculate cloud optical depth was updated.
- xxii) IR and Solar radiance codes were updated to use older-style aerosol table lookups and to pass the calculated properties to the radiance code rather than the base table parameters themselves.
- xxiii) A bug in the clock associated with Solar Insolation Updates within PCHEM was fixed.

#### *Land Surface Component*

- i) Land surface model boundary condition files (topography, LAI, greenness) were updated. MODIS albedo files are now used on a 16-day timescale rather than monthly.
- ii) A bug in the timing of the monthly mean vegetation data (from GSWP-2) and greenness was fixed. These data had previously been introduced 15 days too early.
- iii) The minimum soil depth was increased to 1.333 m (from 1 m).
- iv) A bug that identified a very few low latitude tiles as tundra has been corrected. In previous versions, the SiB vegetation type "Dwarf Trees and Shrubs" was used to identify the LSM vegetation type "Dwarf Trees". Since this particular SiB type is available in small patches outside the Arctic Circle, the LSM now uses "Shrubs" outside the Arctic Circle (about 1.5% land tiles had been affected, but the overall effect in LSM calculations was much smaller).

### **Analysis Changes**

- (i) The analysis moisture variable was changed from q1 (specific humidity) to reformulated q2 (reformulated relative humidity).
- (ii) GSI was updated to accommodate Suomi-NPP, Meteosat SEVIRI, MetOp-B, tiros-n, Meteosat-10 winds, and MLS temperature and moisture retrievals (the last two in reanalysis mode). ATMS from Suomi-NPP is assimilated and the system is CrIS-ready.
- (iii) Updates distinguish drifting buoy from other surface marine observations.
- (iv) CRTM was updated to CRTM\_REL-2.05.
- (v) The GPSRO bending angle is assimilated instead of refractivity.
- (vi) The thinning box for infrared (AIRS, IASI, HIRS) observations was reduced from 180 km to 145 km
- (vii) The thinning box for MHS observations was reduced from 240 km to 145 km.
- (viii) MHS observation errors were inflated due to a misspecification of observation

classification in the GSI namelist.

## **Other**

- i) A bug in GOCART related to ZLE and PBL for CO and CO<sub>2</sub> biomass burning was fixed. The previous code assumed ZLE was height above ground rather than height above sea-level.

## **From GEOS-5.9.1 to GEOS-5.11.0**

### **Model Changes**

#### *AGCM Component*

- (i) The diagnostic PRECTOT = PCU+PLS+SNO, calculated from SURFACE, has been added.
- (ii) The diagnostic names in LANDICE for snow depth and snow mass have been modified to avoid blending within SURFACE.
- (iii) The albedo calculation over Arctic sea ice was updated to be seasonally varying.
- (iv) A bug in the H1000 diagnostic has been fixed.

#### *Land Surface Component*

- i) A new landice component has been introduced that includes a snow model over land ice, improving the albedo calculation.

### **Analysis Changes**

- i) Ozone background error statistics have been updated to be state-dependent.
- ii) The capability to assimilate OMI total ozone with efficiency factors (averaging kernels) was added.
- iii) The vertical length scales for ozone background error correlations were increased by a factor of 2 to give smoother profiles when MLS is assimilated.
- iv) The MHS classification misspecification in the GSI namelist was corrected bringing observation errors to values consistent with 5.7.2 system. The thinning box mesh of 145 km was retained.